March 15, 1888.

Professor G. G. STOKES, D.C.L., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

Professor Oliver Joseph Lodge (elected 1887) was admitted into the Society.

The following Papers were read:—

I. "On certain Mechanical Properties of Metals, considered in Relation to the Periodic Law." By W. CHANDLER ROBERTS-AUSTEN, F.R.S., Professor of Metallurgy, Normal School of Science, and Royal School of Mines, South Kensington. Received March 15, 1888.

(Abstract.)

The author points to the great industrial importance of the influence exerted by small quantities of metallic and other impurities on masses of metals in which they are hidden. He states that this is most marked in the case of iron, and that when Bergman discovered, in 1781, that the difference between wrought iron, steel, and cast iron depends on the presence or absence of a small amount of "graphite," he was astonished at the smallness of the amount of matter which is capable of producing such singular changes in the properties of iron. The evidence as to the importance of small quantities of impurity is quite as strong in other directions at the present day, as is shown by the statement of Sir Hussey Vivian, that one-thousandth part of antimony converts "best select" copper into the worst conceivable, and by the assertion of Mr. Preece, that "a submarine cable made of the copper of to-day," now that the necessity for employing pure copper is recognised, "will carry double the number of messages that a similar cable of copper would in 1858," when the influence of impurities in increasing the electrical resistance of copper was not understood.

Allusion is made to the effect of a small quantity of tellurium on bismuth. Commercially pure bismuth has a fracture showing brilliant mirror-like planes, but if one-thousandth part of tellurium be present the fracture is minutely crystalline. Specimens of such bismuth

were submitted to the Society. The author states that in his own experiments he has employed gold prepared by himself with great care, the purity of which has been recognised by M. Stas. A portion of this gold was recently used by Professor Thorpe in a determination of the atomic weight of gold. Gold was selected for the experiments for the following reasons:—It can be prepared of a very high degree of purity; it possesses considerable tenacity and ductility; the accuracy of the results of the experiments is not likely to be disturbed by the oxidation of the metal or by the presence of occluded gases; and the amount of impurity added to the gold can be determined with rigorous accuracy. The influence of small quantities of metallic impurity in rendering gold brittle has long been known, and is frequently referred to by the older metallurgists, especially by Geber, Biringuccio, and Gellert, and by Robert Boyle. The first systematic experiments on the subject were made by Hatchett at the request of the Privy Council, and were communicated to the Royal Society in 1803. Hatchett concluded that certain metals, even when present in so small an amount as the $\frac{1}{1900}$ part of the mass, will render gold brittle, and he stated that "The different metallic substances which have been employed in these experiments appear to effect gold in the following decreasing order:—1. Bismuth; 2. Lead; 3. Antimony; 4. Arsenic; 5. Zinc; 6. Cobalt; 7. Manganese; 8. Nickel; 9. Tin; 10. Iron; 11. Platinum; 12. Copper; 13. Silver." Mr. Hatchett did not, however, employ pure gold, and in his time the importance of submitting metals to mechanical tests was not understood.

The author then proceeds to describe the results of his own experiments, and he states that in selecting tenacity as the test to which the metal should be submitted with a view to ascertain the effect of the added matter, the following considerations presented themselves. W. Spring has built up alloys by compressing the powders of the constituent metals, and by pointing to the evidence of molecular mobility in *solid* alloys he has done much to show the close connexion which exists between cohesion and chemical affinity. Raoul Pictet considers that there is intimate relation between the melting points of metals and the lengths of their molecular oscillations, the length of the oscillation diminishing as the melting point rises; and, as Carnelley has pointed out, "We should expect that those metals which have the highest melting points would also be the most tenacious." It is known that the melting points of metals are altered by the presence of small quantities of foreign matter, and their cohesion is also thereby altered. The degree of cohesion may thus be investigated either by the aid of heat or by mechanical stress. It might be well to ascertain the amount of change in the melting point of gold produced by the presence of the different elements in small

quantity, but, unfortunately, slight variations in high melting points are very difficult to determine with even approximate accuracy, and it appeared to be better to ascertain the effect of metallic and other impurities on the cohesion of the gold, as indicated by the amount of force externally applied in an ordinary testing-machine, and in that way to ascertain whether the effect of added metals is amenable to any known law.

The purest gold attainable has a tenacity of 7·0 tons per square inch, and an elongation of 30·8 per cent. on 3 inches. Professor Kennedy found that a less pure sample which contained 999·87 parts of gold in 1000, broke with a load of 6·29 tons per square inch; it had an elastic limit of 2·12 tons per square inch, and elongated 18·5 per cent. before breaking. In the following experiments only the purest gold that could be prepared was employed. The effect on the tenacity of gold produced by adding to it about 0·2 per cent. of various metals and metalloids is shown in the following table, in which the results are arranged according to the tensile strengths:—

Name of element added.	Tensile strength.	Elongation, per cent. (on 3 inches).	Impurity per cent.	Atomic volume of impurity.
	Tons per sq. in.			
Potassium........	Less than 0·5.	Not perceptible.	Less than 0·2	45·1
Bismuth.........	0·5 (about)	,,	0·210	20·9
Tellurium........	3·88	,,	0·186	20·5
Lead............	4·17	4·9	0·240	18·0
Thallium.........	6·21	8·6	0·193	17·2
Tin.............	6·21	12·3	0·196	16·2
Antimony	6·0 (about)	qy.	0·203	17·9
Cadmium........	6·88	44·0	0·202	12·9
Silver...........	7·10	33·3	0·200	10·1
Palladium........	7·10	32·6	0·205	9·4
Zinc.............	7·54	28·4	0·205	9·1
Rhodium........	7·76	25·0	0·21 (about)	8·4
Manganese.......	7·99	29·7	0·207	6·8
Indium	7·99	26·5	0·290	15·3
Copper..........	8·22	43·5	0·193	7·0
Lithium	8·87	21·0	0·201	11·8
Aluminium	8·87	25·5	0·186	10·1

Reasons are given for adding the comparatively large amounts of impurity (two-tenths per cent.), notwithstanding that even "traces" of certain metals would have produced very marked effects upon gold, and evidence is adduced to show that exact concordance in the respective amounts of matter added to the gold is not of much importance.

The testing-machine employed is of the form devised by Professor Gollner, and used by him at Prague. It is a double lever vertical machine working up to a stress of 20 tons.

The author points out that these results lead to the conclusion that the tenacity of gold is affected by the elements in the order of their atomic volumes, and he discusses the evidence in favour of this view at some length, pointing especially to the fact that while those elements, the atomic volumes of which are higher than that of gold, greatly diminish its tenacity, silver, which has nearly the same atomic volume as gold, hardly affects either its tenacity or its extensibility. He shows that, so far as the experiments have been conducted, not a single metal or metalloid which occupies a position at the base of either of the loops of Lothar Meyer's curve (which is a graphical representation of the periodic law of Newlands and Mendeléef) diminishes the tenacity of gold, while, on the other hand, metals which render gold fragile all occupy higher positions on Meyer's curve than gold does, and he urges that the relations between these small quantities of the elements and the masses of metal in which they are hidden are under the control of the law of periodicity, which states that "The properties of the elements are a periodic function of their atomic weights." Carnelley has given strong evidence in favour of supplementing the law as follows:—"The properties of *compounds* of the elements are a periodic function of the atomic weights of their constituent elements," and the question arises, May the law be so extended as to govern the relations between the constituent metals of alloys in which, as is well known, the atomic proportions are often far from simple?

The effect on gold of small but varying quantities of metals singly and in presence of other metals, demands examination, and their influence on the specific gravity of gold must be ascertained. Until this has been done no explanation as to the mode of action of elements with large atomic volumes will be attempted.

II. "Report of the Observations of the Total Solar Eclipse of August 29, 1886, made at Grenville, in the Island of Grenada." By H. H. TURNER, M.A., B.Sc., Fellow of Trinity College, Cambridge. Communicated by the Astronomer Royal. Received February 23, 1888.

(Abstract.)

The first part of the paper gives details of the general arrangements made for observation—the selection of a site, the erection of the instruments and a hut to cover them; and refers to the unfavour-